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Study Molding of Vortex state in the Atmosphere

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Abstract

The Earth's atmosphere as a whole has a very complex system of movements that changes over time. The main features of these movements are repeated from year to year and are well displayed on average and climatic maps, which are the starting point for conclusions about the general circulation of the atmosphere. So it is known that the movement of the atmosphere has a vortex character. There are basic states of three-dimensional vortex motion, in which low pressure convergence leads to an upward motion, and high pressure divergence leads to a downward flow in a vortex motion (tornado). These states of the three -dimensional velocity field can be described using the expansion of the convection velocity in terms of stream and potential functions, which describe the spiral structures of this movement. In this paper, simple partial differential equations are introduced that satisfy the ground state of three-dimensional vortex motion. It is also shown that when Re $\to \infty$, the vortex motion degenerates into geostrophic wind, and the corresponding state of vortex motion is replaced by the geostrophic state.

Key words: vortex motion, geostrophic wind, velocity field, vertical component of velocity, ground state.

Introduction

Usually, the state of statics and the disturbance in relation to it in the form of a geostrophic state and an Ekman state are considered as the main states of the atmosphere [1,2,3]. In these models, the vertical component of the wind speed is neglected[4.5]. In the present work, the three-dimensional state of the atmosphere is investigated taking into account the vertical velocity and it is shown that it is vortex[6,7.8]. Writing down the equations describing the steady state dry atmosphere in the local coordinate system (x, y, z), we get:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho_i}\left(\frac{\partial p}{\partial x}\right)+\nu\nabla^2 u+2\omega_{0z}v-2\omega_{0y}w \quad (1)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho_i}\left(\frac{\partial p}{\partial y}\right)+\nu\nabla^2 v-2\omega_{0z}u \quad (2)$$

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$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho_i}\left(\frac{\partial p}{\partial z}\right)-g+\nu\nabla^2 w+2\omega_{0y} \qquad (3)$$

$$\frac{\partial \Delta T}{\partial t}+(\mathrm{v},\nabla)\Delta\mathrm{T}=\mathrm{k}\nabla^2\theta \qquad (4)$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (5)$$

Let's write the expression for the density

$\rho_i=\rho_e(1-\alpha\theta)$.

Static equation:

$$-\frac{1}{\rho_e}\left(\frac{\partial \bar{p}}{\partial z}\right)-g=0.$$

Then the system of equations will be written in the form:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\bar{\rho_e}}\left(\frac{\partial \acute{p}}{\partial x}\right)+\nu\nabla^2 u+2\omega_{0z}v-2\omega_{0y}w \qquad (6)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\bar{\rho_e}}\left(\frac{\partial \acute{p}}{\partial y}\right)+\nu\nabla^2 u+2\omega_{0z}u, \qquad (7)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\bar{\rho_e}}\left(\frac{\partial \acute{p}}{\partial z}\right)+\alpha g\theta+\nu\nabla^2 w-2\omega_{0y}w \qquad (8)$$

$$\frac{\partial \theta}{\partial t}+(v,\nabla)\theta=\Delta\gamma.w+k\nabla^2\theta \qquad (9)$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (10)$$

For horizontal and vertical directions, L and H are taken as length scales, horizontal speed scale direction - U, time scale - L / U, vertical speed scale sti - HU / L, scale for pressure ρeU, the temperature scale is ΔZT[9]. At the same time, we set δ = H / L, Re = UL / v (Reynolds number), Ri = N 2 H 2 / U 2 (Richardson number), N - Brunt frequency, Pr = v / k (Prandtl number), P_{oL} = U / 2ω_{0Z} L (Rossby number),

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$$Po_H = \frac{U}{2\omega_{0y}H}$$

then the dimensionless form for equations (6) - (9) takes the form

$$\frac{\partial\tilde{u}}{\partial\tilde{t}} = -\frac{\partial\widetilde{p'}}{\partial\tilde{x}} + \frac{1}{Ro_L}\tilde{v} - \frac{1}{Ro_H}\tilde{w} + \frac{1}{Re}\left(\frac{\partial^2\tilde{u}}{\partial\tilde{x}^2} + \frac{\partial^2\tilde{u}}{\partial\tilde{y}^2} + \frac{1}{\delta^2}\frac{\partial^2\tilde{u}}{\partial\tilde{z}^2}\right) \quad (11)$$

$$\frac{\partial\tilde{v}}{\partial\tilde{t}} = -\frac{\partial\widetilde{p'}}{\partial\tilde{y}} + \frac{1}{Ro_L}\tilde{u} + \frac{1}{Re}\left(\frac{\partial^2\tilde{v}}{\partial\tilde{x}^2} + \frac{\partial^2\tilde{v}}{\partial\tilde{y}^2} + \frac{1}{\delta^2}\frac{\partial^2\tilde{v}}{\partial\tilde{z}^2}\right) \quad (12)$$

$$\delta^2\frac{\partial\tilde{w}}{\partial\tilde{t}} = -\frac{\partial\widetilde{p'}}{\partial\tilde{z}} + Ri.\tilde{\theta} + \frac{1}{Ro_H}\tilde{u} + \frac{\delta}{Re}\left(\frac{\partial^2\tilde{w}}{\partial\tilde{x}^2} + \frac{\partial^2\tilde{w}}{\partial\tilde{y}^2} + \frac{1}{\delta^2}\frac{\partial^2\tilde{w}}{\partial\tilde{z}^2}\right) \quad (13)$$

$$\frac{\partial\tilde{\theta}}{\partial\tilde{t}} = \frac{1}{\delta}\tilde{w} + \frac{1}{Re}\frac{1}{Pr}\left(\frac{\partial^2\tilde{\theta}}{\partial\tilde{x}^2} + \frac{\partial^2\tilde{\theta}}{\partial\tilde{y}^2} + \frac{1}{\delta^2}\frac{\partial^2\tilde{\theta}}{\partial\tilde{z}^2}\right) \quad (14)$$

$$Where\ Ri = \frac{\mathrm{H}^2\alpha g\Delta\gamma}{\mathrm{U}^2} = \frac{H^2N^2}{U^2}, N^2 = \alpha g\Delta\gamma$$

Thus, omitting the "tilde" sign over the dimensionless quantities, we write:

$$\frac{du}{dt} = -\frac{\partial p'}{\partial x} + \frac{1}{Ro_L}v - \frac{1}{Ro_H}w + \frac{1}{Re}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{1}{\delta^2}\frac{\partial^2 u}{\partial z^2}\right) \quad (15)$$

$$\frac{dv}{dt} = -\frac{\partial p'}{\partial y} + \frac{1}{Ro_L}u + \frac{1}{Re}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{1}{\delta^2}\frac{\partial^2 v}{\partial z^2}\right) \quad (16)$$

$$\delta^2\frac{dw}{dt} = -\frac{\partial p'}{\partial z} + Ri.\theta + \frac{1}{Ro_H}u + \frac{\delta}{Re}\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{1}{\delta^2}\frac{\partial^2 w}{\partial z^2}\right) \quad (17)$$

$$\frac{d\theta}{dt} = \frac{1}{\delta}w + \frac{1}{Re}\frac{1}{Pr}\left(\frac{\partial^2\theta}{\partial x^2} + \frac{\partial^2\theta}{\partial y^2} + \frac{1}{\delta^2}\frac{\partial^2\theta}{\partial z^2}\right) \quad (18)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

If the adjective terms in the equations are omitted and O (δ) = 1, i.e., L = H, then equations (15) - (19) can be transformed. In the course of solving the already transformed system of equations, we obtain a system of equations, we obtain a describing velocity field. In this way,

$$u = -W_0\left(\frac{n\pi}{2k} * sinkx * cosky - \frac{Re}{Ro_L}\frac{2}{2k^2(2k^2+n^2\pi^2)} * coskx * sinky\right)\cos(n\pi z),$$

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$$v = -W_0\left(\frac{n\pi}{2k} * coskx * sinky - \frac{Re}{Ro_L}\frac{2}{2k^2(2k^2+n^2\pi^2)} * sinkx * cosky\right)\cos(n\pi z),$$

$$w = W_0 * coskx * cosky * sin(n\pi z)$$

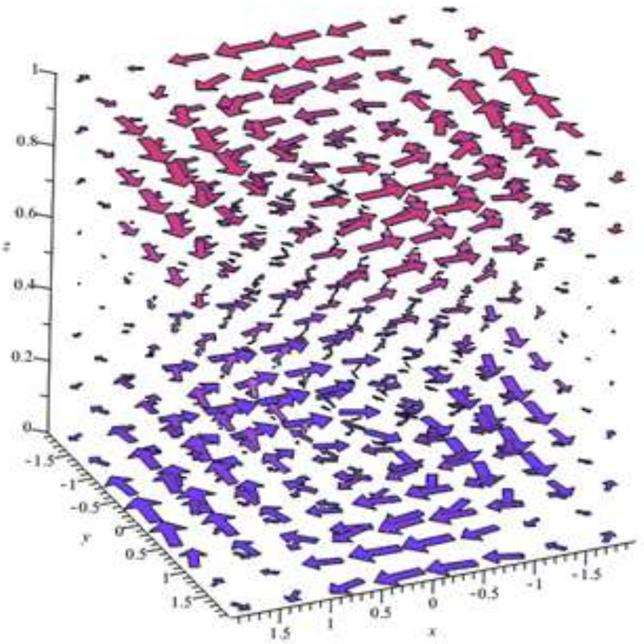

Fig: 1. The velocity field characterizing the movement of the atmosphere. The figure shows the velocity field constructed using the obtained expressions for

The figure shows the velocity field, built according to the obtained expressions for the velocity projections. Analyzing the resulting system of equations, we find that the motion of an air particle takes on a three-dimensional spiral structure (Fig. 1)

The figure shows that for the selected values of the parameters, the air movement has the character of a clockwise spiral twisting. Such a movement occurs up to the vertical middle of the area, then the movement is replaced by the opposite one, i.e. the spiral unwinds counterclockwise.

Conflict of Interests.

There are non-conflicts of interest .

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الخلاصة

الغلاف الجوي للأرض يحتوي ككل على نظام معقد للغاية من الحركات يتغير بمرور الوقت. تتكرر الميزات الرئيسية لهذه الحركات من عام إلى آخر ويتم عرضها جيدًا في المتوسط والخرائط المناخية ، وهي نقطة البداية لاستنتاجات حول الدوران العام للغلاف الجوي. لذلك من المعروف أن حركة الغلاف الجوي لها طابع دوامي. هناك حالات أساسية لحركة دوامة ثلاثية الأبعاد ، حيث يؤدي تقارب الضغط المنخفض إلى حركة تصاعدية ، ويؤدي الاختلاف عالي الضغط إلى تدفق نزولي في حركة دوامة (إعصار). يمكن وصف حالات مجال السرعة ثلاثي الأبعاد هذه باستخدام توسيع سرعة الحمل من حيث التدفق والوظائف المحتملة ، والتي تصف الهياكل الحلزونية لهذه الحركة. في هذا البحث ، تم تقديم معادلات تفاضلية جزئية بسيطة تلبي الحالة الأرضية لحركة الدوامة ثلاثية الأبعاد. يتضح أيضًا أنه عند $Re \to \infty$ ، تتدهور حركة الدوامة إلى رياح جيوستوفيك، ويتم استبدال الحالة المقابلة لحركة الدوامة بالحالة الجيوستوفك.

الكلمات الدالة: الحركة الدوامية ، الرياح الجيوستروفية ، مجال السرعة ، المكون الرأسي للسرعة ، الحالة الأرضية.